



**If you've got it,
Use it
(Simulation, that is...)**



Chad Frost
George Tucker

NASA Ames Research Center

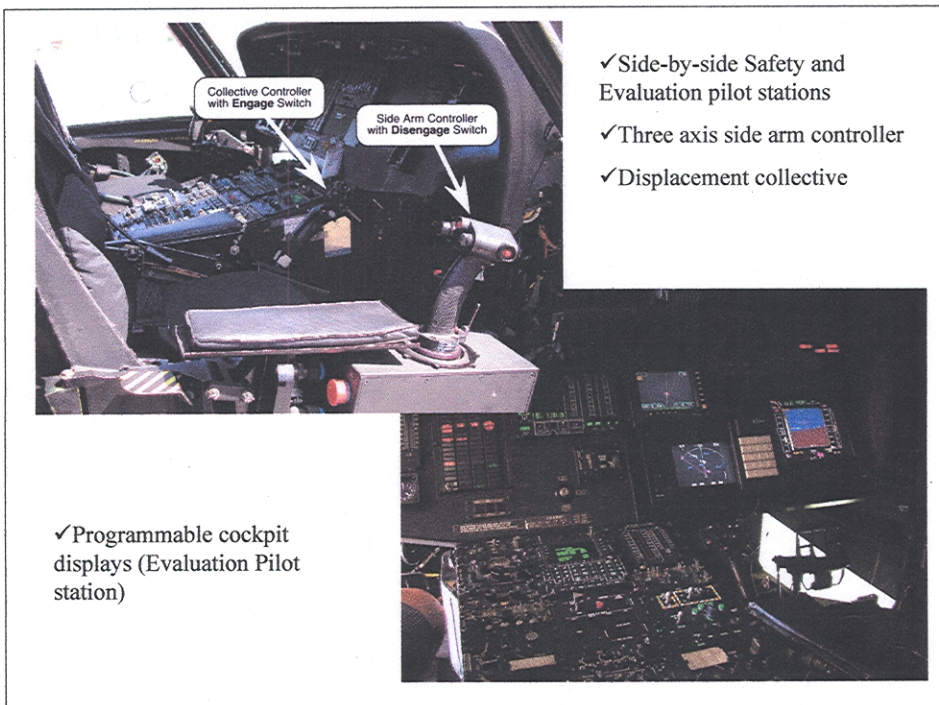
AIAA Workshop
21-24 August 2006
Keystone, Colorado



Presentation Outline

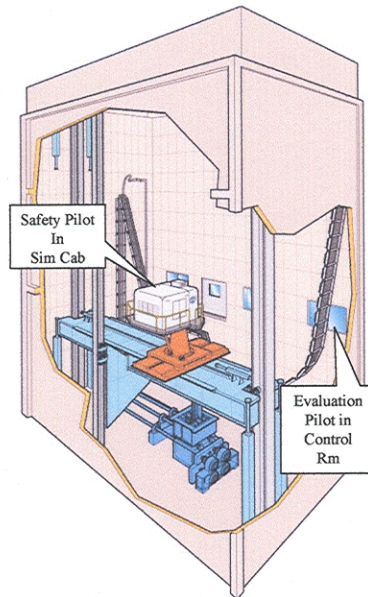
- RASCAL UH-60 in-flight simulator
- Simulation in support of safety monitor design specification development
- Failure/Recovery Rating Scale development
- Use of F/R Rating Scale as a common element between simulation and flight evaluation
- Flight envelope expansion without benefit of simulation
- Summary observations

Rotorcraft Aircrew Systems Concepts Airborne Laboratory (RASCAL)



Simulation Safety Monitor Specification Development

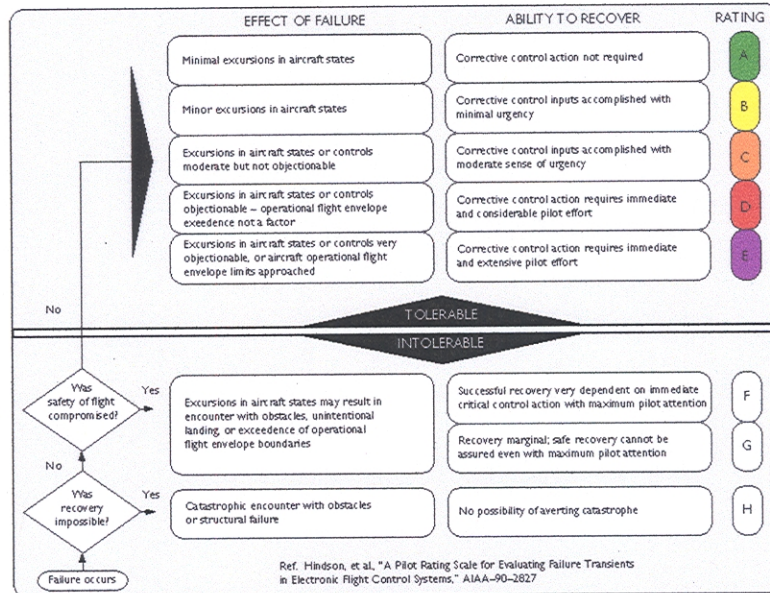
- Large-scale motion simulation used to determine required level of automated FBW system safety monitoring
 - NASA Ames Vertical Motion Simulator
 - Evaluation and Safety Pilot stations in separate locations
 - Multiple candidate flight control implementations investigated
 - Broad spectrum of failure transients injected throughout the anticipated, operational maneuver envelope



Simulation Failure/Recovery Rating Scale Development

- Existing pilot rating scales (e.g., C-H Rating Scale) did not adequately capture the discontinuous nature of failure transients and subsequent recovery effort
- Failure/Recover Rating Scale developed to:
 - Describe effect of failure transients on safety of flight and pilot recovery action
 - Allow correlation of results with existing airworthiness criteria to determine quantitative reliability design goals

Failure/Recovery Rating Scale



Correlation of Failure Ratings with Airworthiness Criteria

- Acceptability of a control system failure is a function of both:
 - The severity of the failure, and
 - Its probability of occurrence
- U.S. and U.K., civil and military design documents used to correlate Failure ratings obtained from simulation with equivalent quantitative probabilities of failure as design guidance

Flight Test Verification

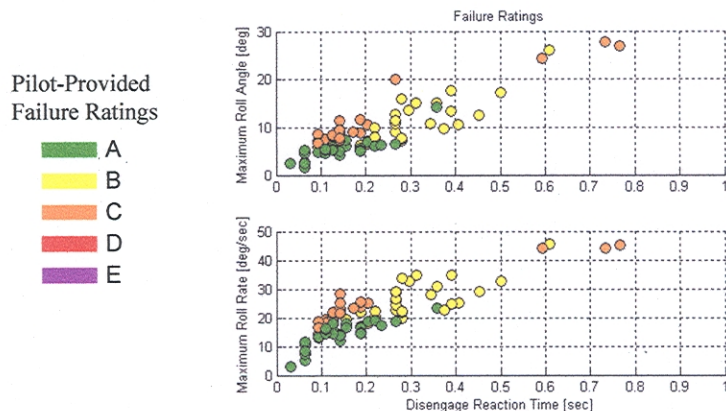
Command Step and Servo Rate Monitors

- Flight conditions: high hover and forward flight
- Simulated single axis failure injections
 - All four cockpit control axes
 - up to 100% of maximum RFCS servo rate
- Failure dynamics and required recovery effort evaluated using the F/R Rating Scale
- Pilot reaction time vs. aircraft excursion evaluated
- In excess of 700 in-flight simulated failures

Representative Flight Test

Results

Lateral Axis Servo Rate Monitor Disengagements



Flight Test Determination

Minimum Safe Operational Altitude

- RASCAL funded to provide risk reduction testing for FBW upgrade of UH-60M
- 60M control laws and control inceptors to be installed in RASCAL and evaluated using the Mission Task Elements of ADS-33E--at published altitudes
 - Arbitrarily-selected minimum engaged altitude to be replaced by “minimum safe operational altitude”
- With simulation not an option, a flight experiment was initiated to define the required minimum altitude

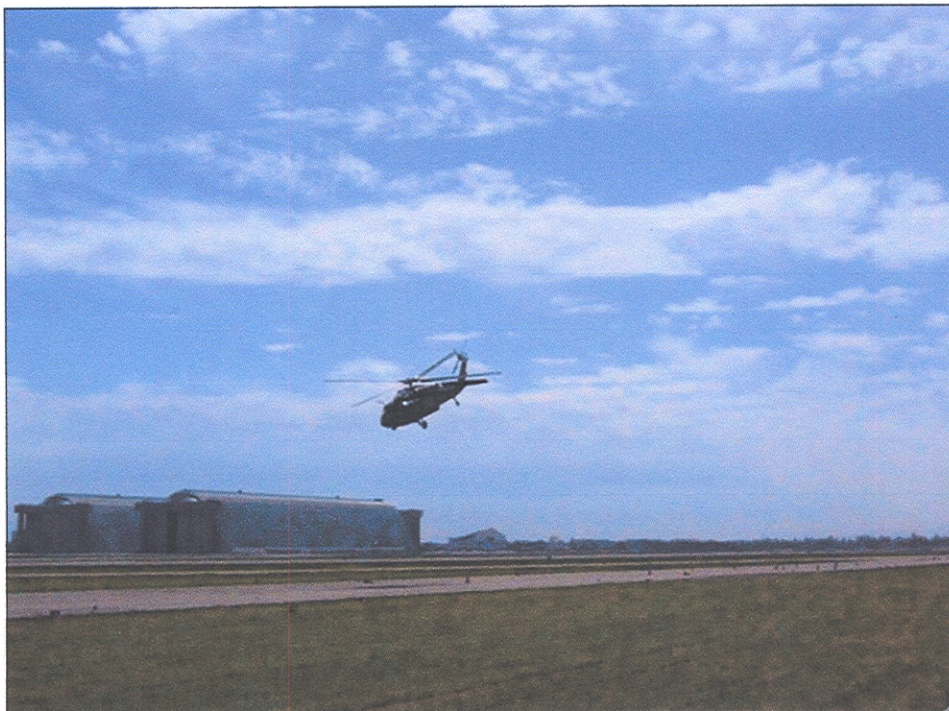
Flight Test Determination (cont.)

Minimum Safe Operational Altitude

- Step 1: Fly each MTE, unengaged, to define necessary maneuvering envelope
- Step 2: Identify attitude responses to a 100% servo rate hardover, with a 0.5 sec disengage time
- Step 3: Re-fly each MTE, unengaged, with safety pilot-induced, simulated failures in most critical axis, at most critical time in maneuver
 - Maximum attitude change the sum of the required maneuver plus the worst case failure.
 - Maneuver altitude decreased until pilot no longer accepting of aircraft state change/recovery requirements

Departure/Abort MTE Maneuver

- Final flare requires approximately +14 deg nose attitude to terminate maneuver
- +27 deg of additional nose up attitude applied to simulate a nose-up pitch hardover at flare termination
- Limit ground clearance approximately 10 ft agl



Lessons Learned from Envelope Determination



- This kind of exploratory work is more appropriately done **in simulation**—when one is available
 - Eliminates risk to a valuable research facility
 - Test conditions more easily repeated for multiple subject safety pilots
 - Test data much easier to collect and analyze

Lessons Learned from Envelope Determination (cont.)

- Positive aspects of doing the envelope testing **in the aircraft**
 - The inevitable “failure recovery training” received by the subject Safety Pilots is very realistic
 - The flight test environment provides a level of Safety Pilot stress absent from simulation under even the best of conditions
 - Safety Pilot subjects have a unique opportunity to validate the published envelope against their own comfort level.

